AIR QUALITY MANUAL

A METHOD FOR ANALYZING AND REPORTING HIGHWAY IMPACT ON AIR QUALITY

REVISED APRIL, 1974

STATE OF CALIFORNIA	TRANSPORTATION LABORATORY
BUSINESS AND TRANSPORTATION AGENCY	**AIR QUALITY MANUAL**
DEPARTMENT OF TRANSPORTATION	**CA-HWY-MR657082S-6-72-14**
DIVISION OF HIGHWAYS	

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration July, 1972

State of California
Department of Transportation
Division of Highways
Transportation Laboratory

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Revised April 1974

FOREWORD

A number of studies must be completed prior to the writing of an environmental impact statement for a highway project. One of these studies is concerned with the gathering of air quality field data, analysis of such data, and the writing of an air quality report.

The California Division of Highways has embarked on a program of equipping and training district personnel to prepare air quality reports. This requires a two-week training course and the preparation of air quality manuals to be used as guides in the gathering of field data, analysis of results, and report writing.

This manual is the sixth in the series of six manuals, the titles of which follow:

1. Meteorology and Its Influence on the Dispersion of Pollutants from Highway Line Sources.

2. Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality.

3. Traffic Information Requirements for Estimates of Highway Impact on Air Quality.

4. Mathematical Approach to Estimating Highway Impact on Air Quality.

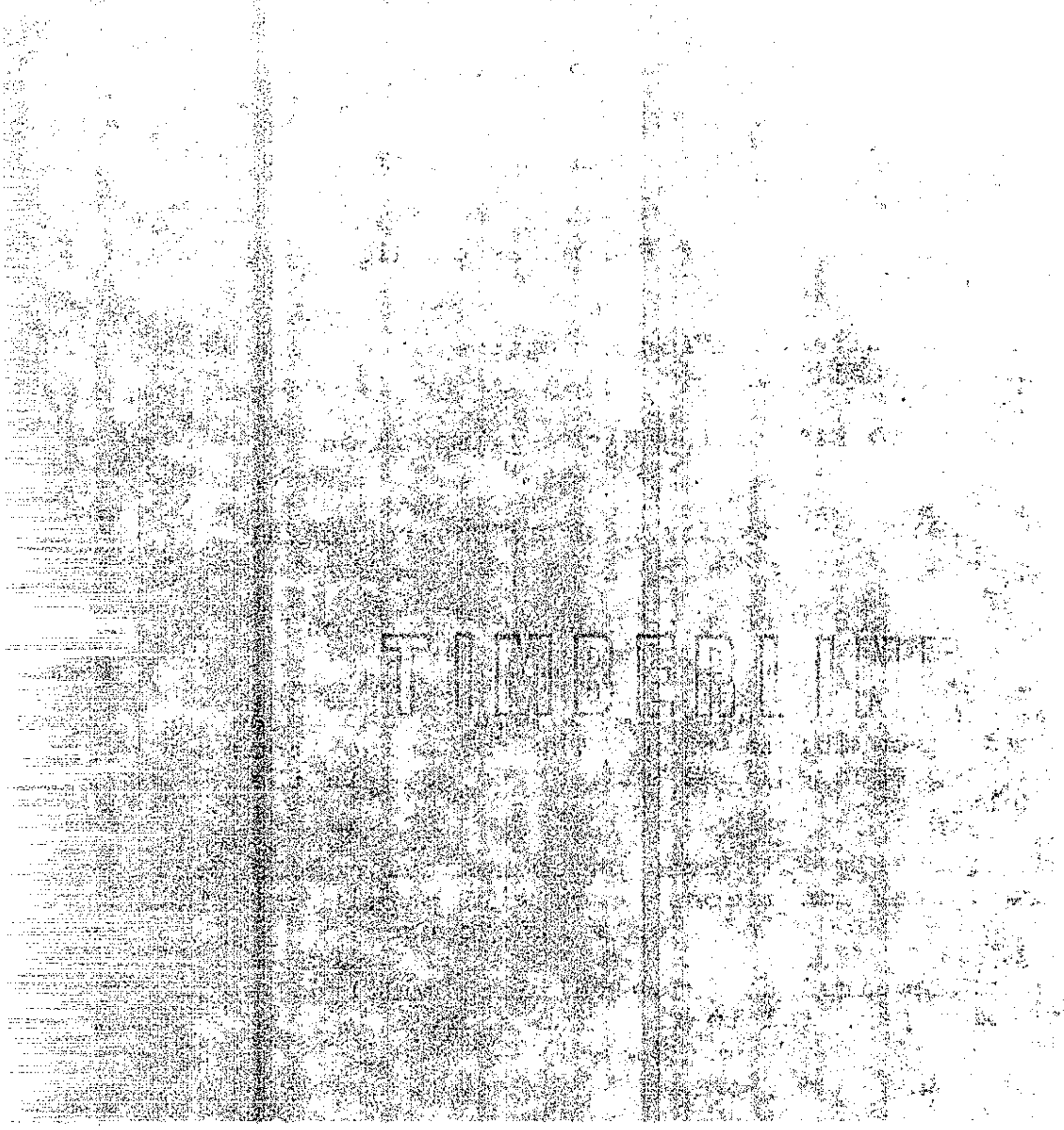
5. Analysis of Ambient Air Quality for Highway Environmental Projects.

6. A Method for Analyzing and Reporting Highway Impact on Air Quality.

The material presented in these manuals is subject to change as further research provides new information. The following items are not discussed or, if presented, are subject to care in the interpretation of results.

1. There are no statistically validated photochemical models for different meteorological conditions which will permit calculations of oxidant formed downwind from a line source.

2. Further research is required to fully validate model calculations when winds blow parallel to the line source.



ACKNOWLEDGMENT

This manual has been authored by Earl C. Shirley under the supervision of John B. Skog, Supervising Materials and Research Engineer, Environmental Improvement Section.

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INTRODUCTION

The modern highway engineer, in addition to his historic responsibilities for planning, designing, building, and operating a transportation system, has become increasingly concerned with the amenities surrounding such a system. Foremost among these amenities are safety, aesthetics, and environmental protection. This manual, and those in the series associated with it, are directed at one aspect of environmental protection, namely that of air quality.

Air pollution resulting from the use of motor vehicles powered by internal combustion engines has had an extraordinary effect upon the quality of life in large urban areas. Effects on man have ranged from minor eye irritation to premature death in some susceptible individuals. Effects on things valued by man range from the premature deterioration of fabrics and rubber compounds to the decay and death of Ponderosa pine in recreational areas.

The engineer, in responding to the need for environmental protection, is motivated by several forces. The first to make an appearance was in the form of a change in public priorities. In certain areas, freeways were no longer welcome neighbors and pressure for environmental protection began to be exerted through neighborhood groups and environmental coalitions appearing at public hearings. The concerns of these groups were eventually expressed in public law, beginning, for all intents and purposes, with the National Environmental Policy Act of 1969. Another federal law, the 1970 Amendments to the Clean Air Act, and a California law, the California Environmental Quality Act, followed in quick succession.

As the movement for environmental protection gained momentum, a driving force from within the profession began to make itself felt. This change began with those engineers who welcomed added public responsibility and regarded environmental protection as a logical expansion of a dynamic profession. Typically, those organizations who were acknowledged leaders in their respective fields were among the first to respond in this fashion.

The development of the series of manuals on air quality impact, of which this one is a part, reflects the professional concern of engineers in the California Division of Highways for protection of the air environment. This particular manual briefly discusses the legal requirements for environmental studies and air pollution phenomena relating to pollutants from vehicles, and then attempts to tie together the subject matter in the five preceding manuals. This subject matter is discussed in terms of a coherent method for analyzing and reporting highway impact on air quality.

LEGAL REQUIREMENTS FOR ENVIRONMENTAL STUDIES

It is important to understand the legal background for environmental studies since public law, in many cases, dictates the manner in which certain aspects of the study must be performed and, in general, dictates the questions which must be answered.

The first major law affecting the work of the Division of Highways with regard to air pollution was the National Environmental Policy Act of 1969. This act created the Council on Environmental Quality. Implementation of this act by the Federal Highway Administration occurred in the form of policy and procedure memorandum (PPM) 90-1. The purpose of this PPM is to provide guidelines to highway departments to assure that the human environment is carefully considered and national environmental goals are met when developing federally financed highway improvements. This PPM reiterates that portion of the law requiring an environmental impact statement for each federally financed project.

Two other important federal laws were enacted in 1970. The first of these, the Clean Air Amendments of 1970, empowered the Environmental Protection Agency (EPA), previously established by executive reorganization, to establish national ambient air quality standards and to require each state to submit a plan providing for implementation, maintenance, and enforcement of such standards in each air quality control region within each state. These plans are termed implementation plans.

The final national law, the Federal Aid Highway Act of 1970, provides for the establishment of general guidelines to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any federal aid system have been fully considered in developing the project. That act also calls for the development of guidelines to assure that highways constructed pursuant to that act are consistent with any approved plans for the implementation of any ambient air quality standard or any air quality control medium designated by the Clean Air Act.

On the state level, the Environmental Quality Act of 1970 promotes the maintenance and enhancement of the quality of life. It requires that all state agencies, boards, and commissions shall include in any report on any project they propose to carry out which could have a significant effect on the environment of the state, a detailed environmental statement.

Figure 1 illustrates the general relationship between these laws.

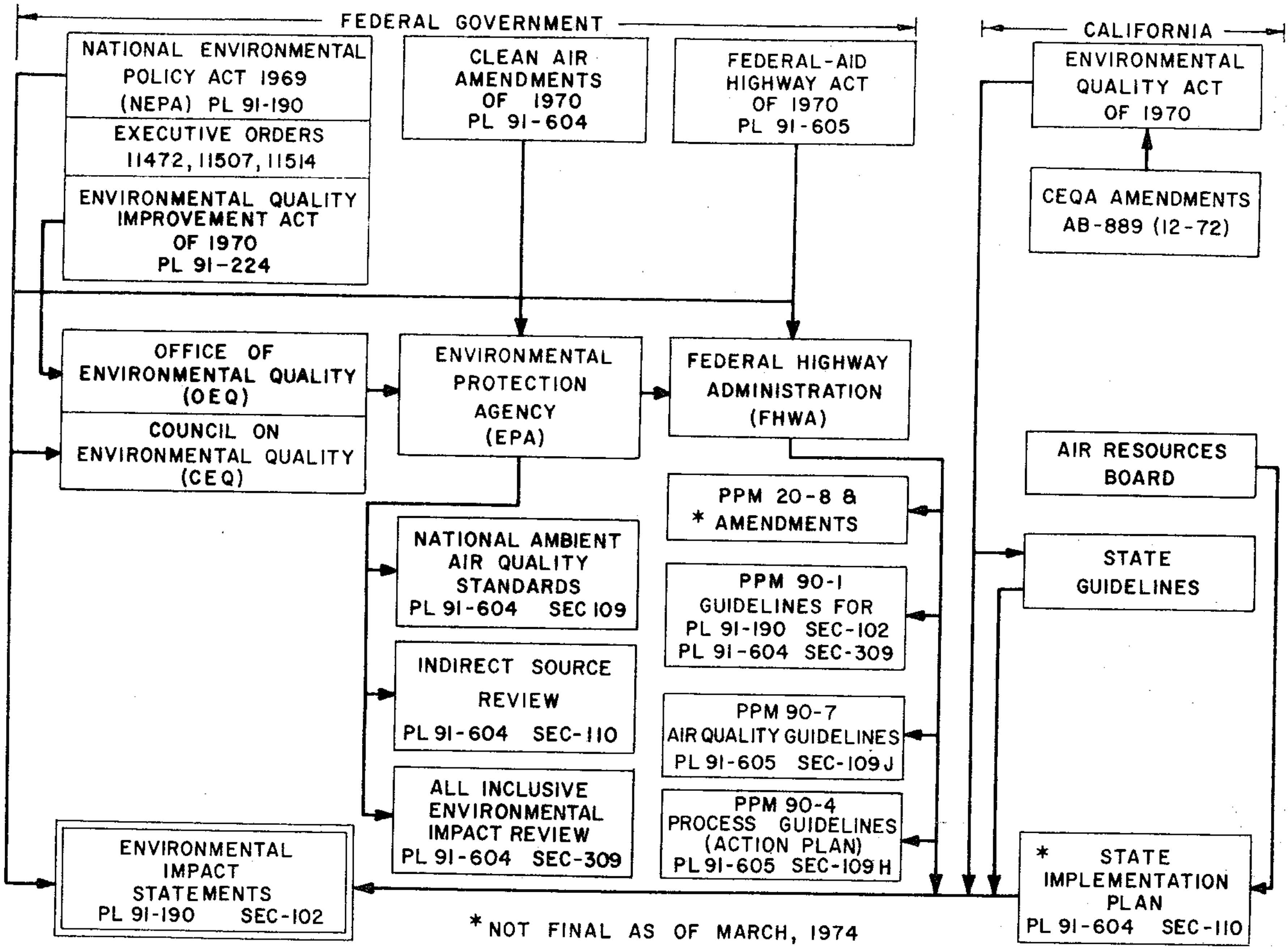


Figure 1 MAJOR LAWS AND REGULATIONS GOVERNING AIR QUALITY IMPACT STUDIES FOR HIGHWAY PROJECTS

The environmental impact statements required by the National Environmental Policy Act of 1969 and the State Environmental Quality Act of 1970 are disclosure documents. The statements should quantitatively examine all positive and negative environmental implications of the project. Mr. William Reilly, of the staff of the Council on Environmental Quality, feels that the environmental statement has three essential functions(1). First, it forces the executive, legislative, and judical branches of the government to scrutinize the attention given to environmental aspects of federal agency decision making. Second, the statement helps an agency to define available options in terms of specific environmental impact in addition to technical and economic considerations. The third function is that of policy guidance.

A good comprehensive air quality study should provide sufficient input to the writer of an environmental impact statement to enable him to answer the following questions concerning the impact of the project upon the air environment:

1) What is the anticipated impact on air quality if the proposed freeway were built? <u>If not built</u>? Both positive and negative impacts should be identified. Both primary and secondary significant consequences for the environment should be included in this analysis. The relation of the proposed project to area-wide air quality should be discussed.

2) What adverse effects on air quality could not be avoided if the proposed freeway were built? <u>If not built</u>? This question requires quantification so that damage to life systems, threats to health, or other consequences adverse to the environmental goals of the National Environmental Policy Act of 1969 can be fully assessed.

3) How would the relationship between local short-term uses of the air resource and the maintenance and enhancement of long-term productivity be affected if the freeway were built? <u>If not built</u>? This requires an assessment of the cumulative and long-term impact of the proposed action on the air environment with the view that each generation is a trustee of the environment for succeeding generations.

4) What irreversible and irretrievable commitments of the air resource would be involved if the freeway were built? <u>If not built</u>? The answer to this question involves identification of the extent to which the proposed improvement would permanently curtail the range of beneficial uses of the air environment.

5) What mitigation measures could be implemented to minimize the impact if the freeway were built? The answer to this question requires the description of mitigation measures which are normally undertaken to offset adverse impact. In the case of air quality, however, research is necessary to identify and evaluate mitigation measures to provide a solid answer to this question.

6) Is the project consistent with the implementation of the National Air Quality Standards?

7) Growth Inducing Factors

Another portion of the environmental impact statement is addressed to the question of alternatives. Since an air quality study involves either a particular route, or a series of alternate routes, the alternatives, with the exception of one, will have been studied. The one alternative remaining is that of not building the project. This alternative must be seriously treated and is reflected in the "not built" query in the questions listed above.

AIR POLLUTION PHENOMENA

Air pollution occurs in many different forms and results from many different sources. The forms of air pollution vary from noxious and highly toxic gases to minute pieces of solid and liquid material. The sources range from dust storms and volcanic eruptions to fires in backyard incinerators.

In the eastern United States, as in most highly industrialized areas throughout the world, the most pervasive form of air pollution is a combination of sulfur dioxide and particulates. This combination exerts a synergistic effect, that is to say, the effect of the combination is greater than the sum of the effects of the two individual pollutants. Other significant pollutants in the eastern United States are carbon monoxide, oxides of nitrogen, and hydrocarbons. From the latter two pollutants, photochemical smog is formed.

In the western United States, where we lack the high sulfur dioxide levels, we substitute the products of photochemical smog. California, with its cities built on flat lands surrounded by mountain ranges, a persistent inversion aloft, the tremendour amount of ultraviolet radiation for which the state is famous, and a high concentration of automobiles in the principal urban areas, is an ideal breeding ground for photochemical smog.

The primary pollutants from the spark ignition internal combustion engine are: Carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbons (Hc), lead, and particulates. Two of the primary gaseous pollutants, oxides of nitrogen and hydrocarbons, react in the presence of ultraviolet light to form secondary pollutants. The principal secondary pollutants which have been identified are ozone (O_3), peroxyacetyl nitrate (PAN), and peroxybenzoyl nitrate (PBN). All of these compounds are very active oxidants and have an extensive effect on health and vegetation.

The principal factors affecting pollutant concentrations are: the downwind distance between the receptor and the source, the wind speed and associated turbulence, the source strength, and the mixing depth.

The greater the distance between source and receptor, the more chance there is for dispersion to occur and hence lessen the concentration. Higher wind speeds have the effect of increasing the amount of air into which the emitted pollutants are dispersed. In effect, this causes a greater dilution. Vertical turbulence, of course, promotes the dispersion of pollutants from a continuous line source such as a highway. The mixing depth directly affects the volume of clean air available to dilute the pollutants.

POLLUTANT EFFECTS ON THE AIR ENVIRONMENT

To properly define an air quality study for a highway line source, a look must be taken at the manner in which the receptors perceive changes in air quality. It is convenient to look at these effects on two levels, microscale and mesoscale.

The receptor living immediately adjacent to the line source is affected when localized pollutant concentrations reach levels injurious to his health. This is the microscale effect and it must be analyzed and quantified in terms of pollutant concentration. The mesoscale effect, as the term would imply, looks at the effect of the project over a much wider area than in the immediate highway corridor. A study on this level is quantified in terms of pollutant burden, that is, tons of pollutant per day per unit area of land surface. Pollutant burden, during episodical conditions, is directly related to ambient pollutant concentrations and, while these concentrations never reach the levels of those found in the microscale situation, they may endure over a sufficiently long period to cause health problems in susceptible individuals.

Biologists use a term, carrying capacity, which defines the number of organisms that may be supported in a particular ecosystem due to the relative presence or absence of some essential item, such as food. In an urban area, carrying capacity or population, might be limited by such things as water, food, air, waste accumulation, or power. Of these items, air is the only one over which man has relatively little control. Hence, it may be convenient to think of mesoscale air quality in terms of carrying capacity.

The effects of the various pollutants on man have been investigated and delineated by epidemiologists. As a result of these investigations, ambient air quality standards have been published by the California Air Resources Board and the Environmental Protection Agency. These standards are shown in Figure 2. It should be noted that these standards were developed to protect those people who are especially susceptible to the effects of air pollutants. These susceptible individuals are primarily the very old and the very young, those with cardiac insufficiencies and anemia, and respiratory cripples.

Industrial air quality standards, however, are directed at healthy individuals and allow substantially higher levels of pollutants. These standards are shown in Figure 3.

COMPONENT PARTS OF AN AIR QUALITY STUDY

Air quality predictions resulting from an air quality study should cover a time period which begins with the present situation and covers a period of approximately 20 years subsequent to the estimated time of completion (ETC) of the improvement. For this period, air quality predictions must be made for two conditions. The first condition assumes the freeway is built, and the second assumes the project is not built.

Determination of pollutant concentrations in the microscale area will be confined, initially, to carbon monoxide, lead, and total particulates. Hydrocarbon concentration will not be predicted since it is not considered by epidemiologists to constitute a health hazard. The primary reason for the inclusion of hydrocarbons in the ambient air quality standards was to effect a control on the formation of secondary pollutants. Oxides of nitrogen will not be predicted in the microscale analysis due to the lack of suitable emission factors showing the variation of these emissions with respect to speed.

Secondary pollutants will not be considered in the microscale analysis since even low wind speeds are usually sufficient to move the reacting pollutant out the microscale area before sizable quantities of secondary pollutants can be formed. Indeed, recent study has shown that ambient ozone within the microscale area is involved in the oxidation of nitric oxide to nitrogen dioxide thereby reducing the ambient levels of ozone in the immediate vicinity. In the future, as suitable emission factors become available, determination of NO_x concentrations within the microscale area will be made.

Figure 2

AMBIENT AIR QUALITY STANDARDS
APPLICABLE IN CALIFORNIA

Pollutant	Averaging Time	California Standards: Concentration[7]	California Standards: Method[1]	Federal Standards[4]: Primary[2,7]	Federal Standards[4]: Secondary[3,7]	Federal Standards[4]: Method[5]
Photochemical Oxidants (Corrected for NO_2)	1 hour	0.10 ppm (200 $\mu g/m^3$)	Neutral Buffered KI	160 $\mu g/m^3$ [8] (0.08 ppm)	Same as Primary Std.	Chemiluminescent Method
Carbon Monoxide	12 hours	10 ppm (11 mg/m^3)	Non-Dispersive Infrared Spectroscopy	---	Same as Primary Standards	Non-Dispersive Infrared Spectroscopy
	8 hours	---		10 mg/m^3 (9 ppm)		
	1 hour	40 ppm 46 mg/m^3		40 mg/m^3 (35 ppm)		
Nitrogen Dioxide	Annual Average	---	Saltzman Method	100 $\mu g/m^3$ (0.05 ppm)	Same as Primary Standard	Colorimetric Method Using NaOH
	1 hour	0.25 ppm (470 $\mu g/m^3$)		---		
Sulfur Dioxide	Annual Average	---	Conductimetric Method	80 $\mu g/m^3$ (.03 ppm)	60 $\mu g/m^3$ (0.02 ppm)	Pararosaniline Method
	24 hours	0.04 ppm (105 $\mu g/m^3$)		365 $\mu g/m^3$ (0.14 ppm)	260 $\mu g/m^3$ (0.10 ppm)	
	3 hours	---		---	1300 $\mu g/m^3$ (0.5 ppm)	
	1 hour	0.5 ppm (1310 $\mu g/m^3$)		---	---	
Suspended Particulate Matter	Annual Geometric Mean	60 $\mu g/m^3$	High Volume Sampling	75 $\mu g/m^3$	60 $\mu g/m^3$	High Volume Sampling
	24 hours	100 $\mu g/m^3$		260 $\mu g/m^3$	150 $\mu g/m^3$	
Lead (Particulate)	30 Day Average	1.5 $\mu g/m^3$	High Volume Sampling, Dithizone Method	---	---	---
Hydrogen Sulfide	1 hour	0.03 ppm (42 $\mu g/m^3$)	Cadmium Hydroxide STRactan Method	---	---	---
Hydrocarbons (Corrected for Methane)	3 hours (6-9 a.m.)	---	---	160 $\mu g/m^3$ (0.24 ppm)	Same as Primary Standard	Flame Ionization Detection Using Gas Chromatography
Visibility Reducing Particles	1 observation	In sufficient amount to reduce the prevailing visibility[6] to 10 miles when the relative humidity is less than 70%		---	---	---

NOTES:

1. Any equivalent procedure which can be shown to the satisfaction of the Air Resources Board to give equivalent results at or near the level of the air quality standard may be used.

2. National Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health. Each state must attain the primary standards no later than three years after that state's implementation plan is approved by the Environmental Protection Agency (EPA).

3. National Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Each state must attain the secondary standards within a "reasonable time" after implementation plan is approved by the EPA.

4. Federal standards, other than those based on annual averages or annual geometric means, are not to be exceeded more than once per year.

5. Reference method as described by the EPA. An "equivalent method" of measurement may be used but must have a "consistent relationship to the reference method" to be approved by the EPA.

6. Prevailing visibility is defined as the greatest vibility which is attained or surpassed around at least half of the horizon circle, but not necessarily in continuous sectors.

7. Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury.

8. Corrected for SO_2 in addition to NO_2.

Figure 3

THRESHOLD LIMIT VALUES*
OF AIRBORNE CONTAMINANTS

SUBSTANCE	PPM	$\mu g/m^3$
Carbon Monoxide (CO)	50	55
Hydrocarbons (Hc)	Variable	
Example - Heptane Many others have no limits so long as sufficient oxygen is available	500	1800
Nitric Oxide (NO)	25	30
Nitrogen Dioxide (NO_2)	5	9
Lead	-	0.15
Inert or "Nuisance Particles"		10

*Values from American Conference of Governmental Industrial Hygienists - 1971.

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit, a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

Threshold limit values refer to time weighted concentrations for a 7- or 8-hour workday and 40-hour workweek. They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations.

For the mesoscale, or total burden analysis, predictions will be confined to the three gaseous pollutants, carbon monoxide, hydrocarbons and oxides of nitrogen. Effects of lead and other particulates are usually limited to the microscale area, since these pollutants, except for some amount in the submicron size range, are acted upon by gravitational forces and are also removed by impaction with surrounding objects. Hence, they will not be considered in the mesoscale analysis. Initially, secondary pollutants resulting from photochemical reactions will not be quantified in the mesoscale analysis. This is due to the lack of a fully validated mathematical model to predict the photochemical reactions. Sophisticated models are now becoming available and, as soon as the validation requirements are satisfied, this capability will be added to our procedures.

In the future, we should gradually proceed toward a system approach since the ambient air quality is a function of the interaction between all the various freeways and the surface traffic network. This is the subject of scheduled research.

It should be recognized at the outset that air quality predictions are somewhat tenuous at best. The predictions resulting from an air quality study are based on statistical analysis of meteorological conditions, statistical analysis of ambient air quality, and statistical analysis of traffic data. These data are then extrapolated perhaps twenty-five years into the future and are used to make air quality predictions. It should be obvious that the reliability of these predictions is open to question. However, the predictions are made using recognized methods and the best data available to anyone. For this reason, no apology need be made concerning the accuracy of predictions.

Characterization of Source Strength

A highway represents a continuous line source of pollutant emissions. The strength of this line source is dependent upon two factors, the first being the volume of pollutants coming from each individual vehicle, and the second being the numbers of these vehicles on the highway at any given time.

The emission factors used in this approach vary with:

1) Vehicle model year mix

2) The percentage of heavy duty vehicles in the traffic stream

3) Speed of the traffic

4) Vehicle operating mode (that is, in the simplest sense, whether the vehicle is on the freeway system or on the surface network)

Emission factors have been developed based on the above criteria. They are presented and fully discussed in the second manual of this series (2). Basically, the model year mix of vehicles composing traffic in California for any particular future year has been estimated. The relative emissions, for each model year vehicle in the mix, are based on the emission controls which were, or will be, in effect at the time of manufacture. These emissions are weighted, based on the percentage of that model year in the mix, and then averaged to provide an emission factor which can be applied to a traffic estimate. Since the emission control devices can be expected to deteriorate as the vehicle accumulates mileage, a deterioration factor was applied to the emission factor. Separate tables were constructed for varying percentages of heavy duty vehicles. Separate factors were also developed for those vehicles traveling on freeways as opposed to the mileage accumulated on surface streets.

Traffic data for source strength calculations in the microscale area consist of speed and volume information at the point where the analysis is being made. This information must be supplied for the critical hours of the day. The critical hours may be determined by peak hour traffic or adverse meteorological conditions.

For the mesoscale, or pollutant burden analysis, total daily mileage and associated average speeds are needed for both freeway traffic and surface traffic. These traffic requirements are detailed in the third manual in this series (3).

At some point in the future, it would be desirable to incorporate a complete traffic network analysis into the procedure for calculation of mesoscale air quality impact.

Transport and Dispersion of Pollutants

The transport and dispersion of air pollutants depends upon topography and meteorology. The very important first step in any study of transport and dispersion is that of laying out and examining, on a topographical map, all the features which might affect the air quality study. As a general starting point, it would be well for each district to acquire Hubbard Raised Relief Maps covering the entire district. These maps have a scale of 1:250,000 and cost about $10 each. These maps are available from:

Pasadena Map Company
148 East Colorado Boulevard
Pasadena, California 91105

For specific projects, a 15 minute quadrangle (scale = 1:62,500) is about right. The scale selected should be small enough so that the area covered will allow inspection of wind flow into and out of the area, and yet large enough so that station locations and other important features can be plotted. In this regard, the following steps should be taken:

1) Plot the location of all air quality data sources.

2) Plot the location of all meteorological data sources.

3) Delineate natural and man-made features which might affect windflow.

4) Plot the location of the most sensitive receptors such as hospitals, schools, and rest homes as well as the features of medium sensitivity such as residential areas.

5) Plot the location of existing and future point sources of pollution such as factories and power plants.

6) Plot the location of areas with susceptible agricultural crops which are downwind of the project in the area where secondary pollutants might be expected to form.

7) Examine land use plans for the future location of receptors and plot these.

8) If sufficient data are available from the plotted meteorological stations, prepare wind rose plots and superimpose these on the topographic map.

9) If sufficient data are available, prepare overlays showing wind streamlines for the typical meteorological regimes.

10) Examine the plotted data and locate the areas where field studies will be required to obtain additional desired meteorological and air quality data.

A meteorological study is an essential element of any air quality analysis. Only in this manner can the transport and dispersion of pollutants be estimated. The first step is to locate all existing data for the area under study. These data should be analyzed and wind roses developed. The desirable parameters for this analysis are wind direction, wind speed, stability for various regimes, inversion heights or mixing depths, and, if data are available, wind streamlines. The first report in this series discusses sources of these data and methods for analysis (4).

There will be few cases where the existing data fully satisfy the data requirements for the project. Normally, data will have to be developed for each individual project. These data will be developed in distinct phases. The first step will be to obtain data, using mechanical weather stations at desirable locations, to characterize wind speed and direction. Collection of these data might take as long as a year. Where possible, inversion heights for the various meteorological regimes should be taken simultaneously with the other measurements. If instrumentation is available, twice daily flights from a nearby airport would satisfy this requirement. Calibration of any instrumentation used is essential.

The second phase for developing data involves an examination of the temperature structure and turbulence in the lower atmosphere. This can be accomplished by locating a meteorological tower on previously selected sites for short periods under the various meteorological regimes. The towers to be used by the Division of Highways carry two sets of wind speed and direction instruments separated by an interval of 10 meters to examine wind shear. They also carry instrumentation for measuring temperature change over the same interval. This instrumentation is self-contained and capable of operating without support for more than a week at a time.

In any areas where wind flow patterns vary considerably due to topographical influences, it is desirable to obtain meteorological data which will allow construction of wind streamlines. For the microscale situation, these streamlines can be constructed with the use of hand held anemometer and direction indicator. For the mesoscale situation, the use of balloons and theodolites is recommended.

Evaluation of meteorological information will involve the "most probable" meteorological conditions and the "worst case" meteorological conditions. The probabilities of occurrence of these conditions must be estimated. For each of these conditions, a wind rose and stability analysis must be made. These analyses must be correlated with hours of peak traffic flow and any anomalous traffic situation which may give rise to an increase in source strength. Conversely, traffic data must be collected for the "worst case" meteorological conditions. Analyses made in this manner enable the evaluation of the most critical conditions. Methods of analysis are fully discussed in the manual on meteorology which is the first manual in this series (4).

Mathematical Analysis

Analysis of pollutant concentration in the microscale area is made using a mathematical model. Inputs to this model consist of traffic data, meteorological data, and emission factors. The output from this model is presented in terms of concentration of the pollutant being analyzed for a particular meteorological regime and a certain traffic condition. To these predictions must be added the ambient concentration of the pollutant in question.

The mesoscale analysis is primarily concerned with the total pollutant burden resulting from changes in the traffic network which accompanies the initiation of a new traffic facility. The item of greatest importance in this analysis is the change in the total amount of daily vehicle mileage in the affected traffic network and the average operating speeds at which that mileage is generated. Another aspect of mesoscale analysis is the import of primary and secondary pollutants from distant upwind sources into the study area and the export of primary and secondary pollutants generated within the study area to distant downwind receptors.

The final aspect of a complete mesoscale analysis is the examination of the time history of oxidant concentration and the prediction of future trends based on correlation with future pollutant burden estimates. The fourth manual in this series presents a mathematical model for estimating microscale concentrations and treats the mesoscale analyses in detail (5).

Ambient Air Quality

A study of ambient air quality serves to define the background levels of pollutant concentrations in the project area. Like the meteorological study, an ambient air quality study must begin with the collection and analysis of the existing or historical data.

Since it is highly unlikely that sufficient data exist to define ambient air quality along a proposed route, particularly in areas along the route containing sensitive receptors, it is mandatory to perform an on-site survey. The first level of sophistication in such a survey is to obtain bag samples of air for later analysis. The only gaseous pollutant for which values can be obtained without some degree of degradation is carbon monoxide. The necessary equipment for this survey is a number of 12" x 18" Scotchpak bags, a battery powered air pump, and a well calibrated, sensitive nondispersive infrared carbon monoxide analyzer. Lead and particulates can be sampled with a high volume sampler and subsequent analysis for lead performed with atomic absorption equipment. Continuous meteorological observations must be taken on-site during the gathering of any air samples.

The second stage of sophistication for an air quality survey involves the use of an instrumented van. The vans used by the Division of Highways contain a long path nondispersive infrared analyzer for carbon monoxide, an ultraviolet absorption analyzer for ozone, a chemiluminescent analyzer for nitric oxide and nitrogen dioxide, and a high volume sampler for lead and particulate samples. These mini-vans contain onboard power with a capability for connecting to house current. Each mini-van has an onboard anemometer and wind direction indicator. Data are acquired graphically and onboard capability for calibration is maintained.

Data gathered during an ambient air quality study serves several purposes. The main purpose, naturally, is that of providing background air quality data. Secondary purposes involve the building of a data bank (this applies particularly to NO_x and O_3 data), mathematical model validation, and analysis of source strength predictions. Where NO_x and O_3 are traceable to upwind highways, traffic data should be obtained during sampling periods.

The periods during which ambient air quality data are gathered must be closely tied with the periods for the meteorological survey and the periods for which traffic data are estimated. Again, the object is to acquire data for the "most probable" conditions and the "worst case" conditions. Air quality data must be taken for periods corresponding with the various averaging times listed in the ambient air quality standards.

The final phase of the ambient air quality study is the prediction of future ambient air quality. This prediction can be based in part on an extrapolation of the correlation between historical pollutant burden and historical ambient air quality. To this extrapolation must be added the effects of future changes in land use and probable future point sources. The fifth manual in this series presents the analysis of ambient air quality in detail (6).

DATA PRESENTATION

One of the most difficult aspects of any report lies in the communication of the significant findings to other people. In the case of the air quality report, the findings will be incorporated into an environmental impact statement by another person. This statement will then be used as a basis for decision making by still other people. It is very probable that the findings from the air quality study, in addition to being used in the environmental impact statement, will be used as a basis for discussions in a public hearing. It is, therefore, doubly important that the findings be communicated in a manner which promotes understanding and enables analysis by a reasonable layman.

It is entirely possible to address a report to two levels of understanding. The needs of the technically oriented person may be satisfied by presenting detail in the body of the report while the reasonable layman, with the aid of written, tabular, and graphic data summaries, should be able to arrive at a full understanding of the findings.

The number of variables to be discussed in an air quality report taxes the ingenuity of the report writer who is attempting to communicate his findings. Air quality must be discussed with the improvement and without it. The "most probable" and the "worst case" pollutant concentrations must be presented and the probabilities of their occurrence discussed. The time period for the study must begin with the existing situation and continue through the completion of the improvement and for twenty years thereafter. The effects of the pollutants must be discussed in terms of the distance between the receptor and the source. The pollutant concentrations must be discussed in terms of health standards, that is, the one hour, eight hour, twelve hour, yearly and other averages as required must be presented for the pollutants to which they apply. To compound the above variables, each pollutant requires a separate discussion.

WRITTEN AND TABULAR DATA SUMMARY

The following items should be presented in tabular form with sufficient written discussion for each item to fully explain the data.

1) Ambient air quality data should be shown in a form that will clearly indicate the existing air quality, the air quality at the end of the design life of the project, and the intervening trends. If the trends indicate a peak or a valley, both the poorest and the best air quality should also be indicated.

2) The pollutant burden and its variations over the same time period should be presented. A short discussion should cover the probability of episodical conditions and the effects of those conditions on the pollutant burden.

3) The import and export of pollutants, where applicable, should be discussed. The relative effect of these phenomena should be presented.

4) The oxidant trends with respect to time should be presented in terms of the number of adverse days, which might exceed the health standards, on a yearly basis over the period of the study.

5) Microscale pollutant concentrations should be shown for the "most probable" and "worst case" conditions. The respective probabilities of occurrence of these conditions should be indicated. Some detail should be presented with regard to areas where sensitive receptors are located. The data should also be presented in a manner which will indicate the variation in concentration with respect to the distance from the source.

VISUAL AIDS

One of the best avenues of communication between the engineer and the layman is that which utilizes visual aids such as charts, graphs, and sketches. This approach, however, is often abused and fails to achieve its purpose due to the amount of detail on any one chart which the eye is required to assimilate. Simple visual aids, with minimal detail and the bold use of color, are the epitome of good communication. The principal use of the visual aid should be to present trends and comparisons. The tabular and written summaries, discussed previously, are slightly more sophisticated and present some detail. The body of the report provides even finer detail and technical discussion for those who are interested.

Graphic presentation of trends, with time as the horizontal axis, can effectively demonstrate changes in mesoscale pollutant burden, oxidant trends, and ambient air quality.

The mesoscale pollutant burden trends could be indicated with one color for the situation including the improvement and one color for the situation without the improvement. Horizontal limit lines could then be drawn with one line indicating the maximum acceptable pollutant burden under the most probable meteorological conditions and another limit line indicating the maximum acceptable burden under episodical conditions.

The trends in average ambient air quality can be indicated with a single line for each pollutant. However, since a comparison must be made with the averaging times called out by the health standards, several charts for each pollutant may be required. The applicable air quality standard should be indicated by a horizontal line on the appropriate charts.

Oxidant trends with respect to time can be appropriately visualized by two different colored lines on a chart representing the situation with the improvement and the situation without the improvement.

Contour maps may be an effective way of visualizing microscale pollutant concentrations. This could be done using a plan view of the project and the surrounding community with perhaps three colors representing ranges of pollutant concentrations. One chart could thus indicate spatial variations in pollutant concentrations for the combination of a particular meteorological regime and source strength. The color RED could be used to indicate those concentrations which exceed the health standards.

The question of pollutant transport may be dealt with by a two color presentation which indicates the relative amounts of transported oxidant and oxidant formed from pollutants generated within the area.

RESPONSE TO QUESTIONS FOR THE ENVIRONMENTAL IMPACT STATEMENT

Response to the questions to which the environmental impact statement must address itself should be made in the air quality study. The statements must be quantified insofar as possible. This may be done by listing the changes in air quality in terms of tons per day or parts per million.

The ultimate effect of air pollution, however, as it applies to human health, agricultural losses, wear and soiling of clothing and other fabrics in the home, corrosion and wear of metals, paints, and susceptible materials, extra industrial maintenance, aesthetic losses, degradation in work performance, decline in property values, and visibility reduction is very complex and practically incapable of estimation. If the changes in quantities and concentrations of air pollutants are very small, it should be pointed out that the effects on the air environment would be small also. If, however, the changes are substantial, it is best to leave the evaluation of the effects of the change up to competent epidemiologists, plant pathologists, and other such experts.

REPORT OUTLINE - AIR QUALITY STUDY

The following outline is offered as a suitable format in which to report an air quality study. It is not the intent of this manual that the format for a study should be rigid and inflexible. There are many cases in individual studies where the report writer will have to depart from the proposed format to provide a coherent report. Figure 4 shows the proposed outline in a flow chart format.

In general, a report on an air quality study should contain the following subdivisions:

1) Project description. This should be a short narrative statement of not more than a few paragraphs describing the proposed improvement in sufficient detail to allow a reviewer to obtain a mental picture of the work to be done.

2) Conclusions. The conclusions are presented early in the report to enable a cursory review by the person who does not desire to dig through the detail. In the conclusions, the first thing to be discussed should be the answers to the questions for the environmental impact statement. Secondly, the written and tabular data summaries should be presented. The final portion of the conclusions, the graphic data presentations, can be interspersed with the written and tabular data summaries if desired.

3) Background discussion. This section should provide a resume of all the historical data that were researched for the study. These data should be presented under the following general topics:

    a) Topography. This should include a copy of the map discussed earlier in this manual.

    b) Historical meteorology.

    c) Historical air quality.

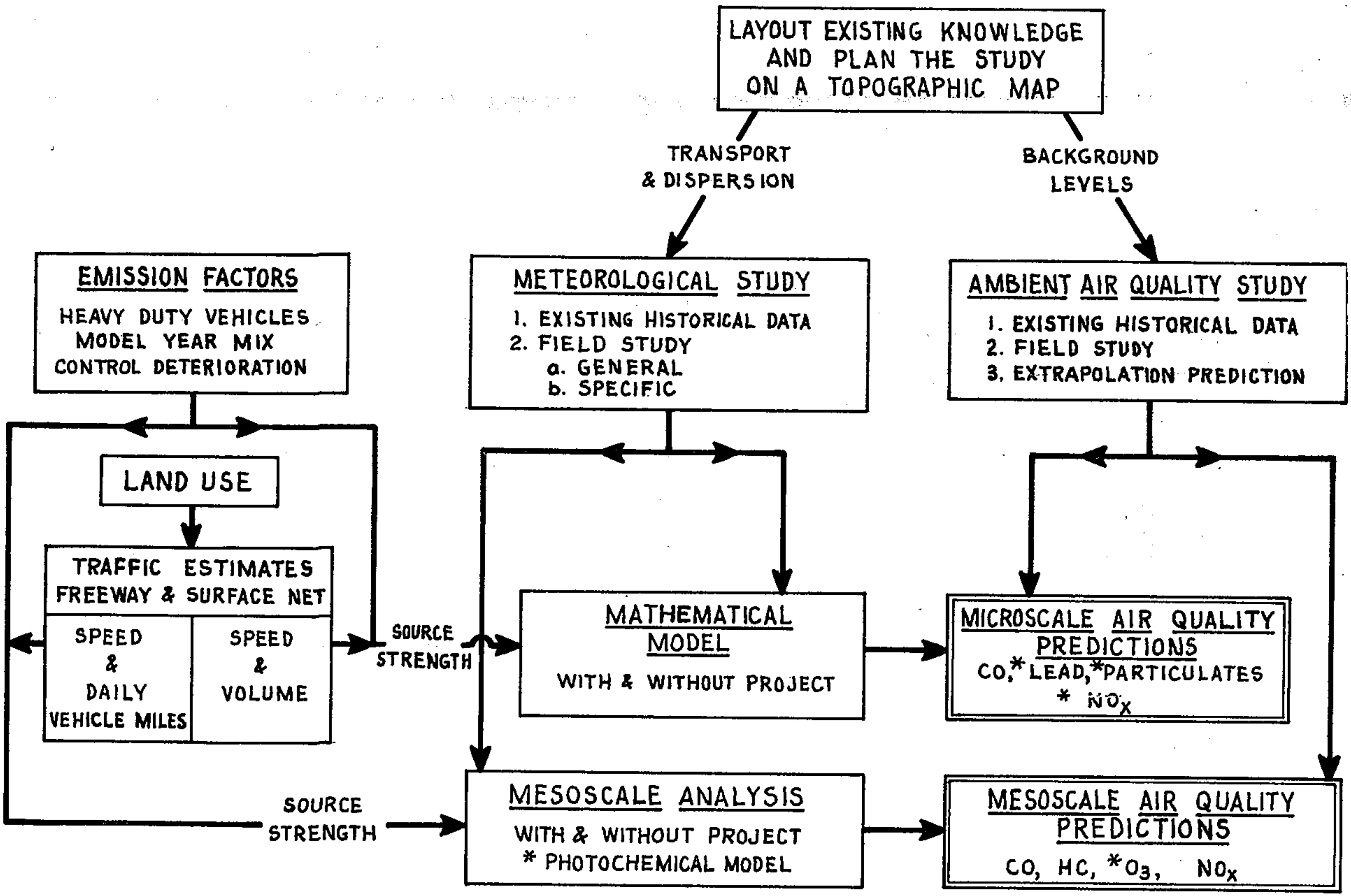
    d) Principal existing point and line sources.

    e) Existing and future land use.

    f) Existing and future sensitive receptors.

    g) Research of previous studies.

PROCEDURE FOR ANALYZING HIGHWAY IMPACT ON AIR QUALITY



* TO BE ADDED AT A LATER DATE.

FIGURE 4

4) Description of Field Studies. The field studies should be fully described including the instrumentation used, calibration of that instrumentation, dates and locations where observations were made, and a discussion of the setups at the various points. This section should be divided into two subsections:

   a) Meteorology, including data reduction and results.

   b) Ambient air quality, including data reduction and results.

5) Traffic Estimates. The source of these estimates should also be given if data sources other than the Division of Highways were used. These estimates should also be tied in with the discussion of the existing and future land use under 3e above.

6) Emission Factors. A brief discussion of the derivation of the emission factors should be presented in this section. The basis for this can be found in the second manual in this series.

7) Mathematical Analysis. This section should cover the use of the mathematical model to estimate microscale concentrations and the various mesoscale analyses that were made. The fourth manual in this series should be referenced as the source of the mathematical model should a reviewer wish to obtain more detail.

8) Bibliography. In this section the sources of historical data used in the report, sources for statements that may have been made, and references to this series of air quality manuals should be listed for the benefit of the reviewers.

9) Appendices. If desired, the reduced meteorological and ambient air quality data from the field studies may be attached to the report in appendix form. The appendices should be attached only to those reports going to interested agencies such as the Air Resources Board and the Department of Public Health. The average reviewer will be interested only in the data summary.

BUILDING AN AEROMETRIC DATA BANK

To facilitate future air quality studies and provide for complete mathematical model validation, it is essential that a straightforward method for storing and retrieving data be developed. The method to be used by the Division of Highways is based on optical coincidence as described in the report by Sherman and Anderson (7). The specific application of this method to the storage and retrieval of aerometric data is the subject of a future report.

OUT-OF-HOUSE STUDIES

Variability in workload, complexity of the studies, and certain other factors may make it desirable to use a consultant in the performance of an air quality study. To facilitate the hiring of such a consultant, a request for proposal (RFP) has been developed. The study outlined in the RFP, in a different format than that shown in this manual, has been structured to allow the consultant a certain latitude in using his expertise to develop the best possible approach. The recommended form for a request for proposal is shown in Appendix A.

SYSTEMS APPROACH TO AIR QUALITY STUDIES

It would be desirable, as soon as possible, to go to an integrated systems approach for the analysis of transportation impact on the air environment. If it were possible to develop an integrated transportation plan for an existing urban area, an air quality study could be made which could fully evaluate the interactions as the various parts of the transportation network were constructed and brought into the system. In the planning phase, it would be possible to bring air quality consideration into the decisions for the location of highway corridors.

As a beginning, with the development of the aerometric data banks in the Highways districts, each district should begin to construct an air quality hazards map. This map would be an informational aid to the highway planner and would indicate areas having higher probabilities of poor air quality based on topography, meteorological consideration, and historical ambient air quality.

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1. Highway Research Board, "Environmental Impact Statements: A View in Three Dimensions," Number 126, Washington, D.C., April 1971.

2. Beaton, J. L., Skog, J. B., and Ranzieri, A. J., "Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality," State of California, Department of Public Works, Materials and Research Department, Air Quality Manual No. CA-HWY-MR657082S(2)-72-10, April 1972.

3. Beaton, J. L., Skog, J. B., and Shirley, E. C., "Traffic Information Requirements for Estimates of Highway Impact on Air Quality," State of California, Department of Public Works, Materials and Research Department, Air Quality Manual No. CA-HWY-MR657082S(3)-72-09, April 1972.

4. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J., "Meteorology and Its Influence on the Dispersion of Pollutants from Highway Line Sources," State of California, Department of Public Works, Materials and Research Department, Air Quality Manual No. CA-HWY-MR657082S(1)-72-11, April 1972.

5. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J., "Mathematical Approach to Estimating Highway Impact on Air Quality," State of California, Department of Public Works, Materials and Research Department, Air Quality Manual No. CA-HWY-MR657082S-4-72-12, May 1972.

6. Beaton, J. L., Skog, J. B., Shirley, E. C., and Ranzieri, A. J., "Analysis of Ambient Air Quality for Highway Environmental Projects," State of California, Department of Public Works, Materials and Research Department, Air Quality Manual No. CA-HWY-MR657082S-5-72-13, May 1972.

7. Sherman, G. B., and Anderson, R. A., "Document Retrieval in a Highway Research Library," State of California, Department of Publice Works, Materials and Research Department, Highway Research Report M&R No. 631140, April 1968.

APPENDIX A

*REQUEST FOR PROPOSALS FOR
AN AIR QUALITY STUDY

*An actual request for proposals used by District 04 is presented in this example.

REQUEST FOR PROPOSAL

REASON FOR STUDY AND EXACT LOCATION

The Division of Highways is required to prepare a report on the environmental impact of each new highway project. One part of this report deals with the present and future air quality.

The present need is for an air quality study which covers the Route 101 bypass of the City of Cloverdale in Sonoma County from Hiatt Road to Preston Overhead. It is proposed that this project be analyzed by a private consultant for impact on air quality within the geographical region shown on the attached Location and Freeway Strip Map.

STUDY OBJECTIVES

In general, the study shall provide answers, quantified where possible, to the following questions:

1. What is the anticipated impact on air quality if the proposed freeway were built? If not built?

2. What adverse effects on air quality could not be avoided if the proposed freeway were built? If not built?

3. How would the relationship between local short-term uses of the air resource and the maintenance and enhancement of long-term productivity be affected if the freeway were built? If not built?

4. What irreversible and irretrievable commitments of the air resource would be involved if the freeway were built? If not built?

5. What mitigation measures could be implemented to minimize the impact if the freeway were built?

6. Is the project consistent with the implementation of the National Air Quality Standards?

Answers to these questions shall consider demographic projections, land use patterns, and surface street traffic estimates provided by local planning groups and agencies. For the "not built" case, close attention shall be paid to anticipated development and traffic growth on the surface street network.

STUDY OBJECTIVES (CONT'D)

Specifically, the study shall provide quantified solutions in the following areas:

1. Define existing ambient air quality under typical meteorological regimes using as indicators: CO, NO_x, O_3, hydrocarbons corrected for methane, particulates, and lead. Existing ambient air quality shall be defined in detail with respect to the proposed corridor (microscale) and in general with respect to the immediate portion of the air basin (mesoscale).

2. Predict future ambient air quality with and without the freeway at the estimated time of completion of the freeway and for twenty years thereafter under typical meteorological regimes using as indicators: CO, NO_x, O_3, hydrocarbons corrected for methane, particulates, and lead. Typical meteorological regimes shall include the "most probable" regime and the "worst case" regime. Probabilities of their occurrence shall be estimated. Future ambient air quality shall be estimated in some detail with respect to the corridor (microscale) and in general with respect to the immediate portion of the air basin (mesoscale).

SCOPE OF THE WORK

The study shall encompass a sufficient span of time and shall include a sufficient number of data points to ensure statistically valid meteorological and existing ambient air quality data. Particular attention shall be paid to those meteorological and topographical features which might tend to concentrate pollutant emissions.

Sufficient data shall be collected both to characterize existing ambient air quality, and to predict future ambient air quality during the "most probable" meteorological regime and under "worst case" conditions when the area is under the influence of an extended adverse meteorological regime.

Meteorological measurements shall be sufficient to characterize wind movement in the study area and provide answers to the questions of pollutant transport and dispersion. Exposure of meteorological equipment should meet the standards established by the World Meteorological Organization (WMO) and the National Oceanic and Atmospheric Administration (NOAA) for surface wind measurements. Use shall be made of existing sources of data. The consultant shall restrict his primary meteorological measurement techniques to any or all of the following: wind shear, lapse rate, vertical direction, horizontal direction, horizontal velocity, vertical velocity, vector velocity, humidity, barometric pressure, zero-lift balloon trajectory and pilot balloons. If he desires, the contractor may supplement his primary techniques with nontoxic fluorescent gas or particulate tracers. Consideration should be given, however, to the use of the simplest practicable techniques.

A meteorological work plan, including stations, instrument locations, and type and duration of observations should be furnished by the contractor in the proposal. It is expected that this will require an on-site study of the area prior to furnishing a proposal. The proposed meteorological work plan will be evaluated by the Division of Highways staff and a meteorological consultant.

Ambient air quality data shall be collected at a sufficient number of sites to characterize pollutant levels in the study area. Particular attention shall be paid to existing point sources of pollutants and to the more sensitive receptors such as hospitals and schools. Use shall be made of existing data sources. The use of advanced state-of-the-art sensors is encouraged. Locations and exposures chosen primarily on the basis of convenience will not be acceptable. Traversing with a moving air monitoring van to determine ambient air quality will not be acceptable.

All equipment, including meteorological equipment, air analyzers, and recorders, shall be calibrated during the study at intervals which are sufficient to maintain desirable accuracy. Calibration records shall be maintained. The methods of calibration chosen shall bracket the ranges used in the study.

Prediction of future pollutant levels shall take into account the following factors:

1. Demographic projections,

2. Changes in automobile emissions with model year,

3. Make up of traffic (model year mix),

4. Changes in vehicle operating mode and trip length (City streets vs. freeways),

5. Use of nonleaded gasoline,

6. Changes in land-use patterns,

7. Volume of traffic,

8. Variation in traffic volume with time of day.

Demographic projections and changes in land-use patterns shall be estimated based on existing available projections by local agencies. Traffic data and vehicle emission factors will be supplied by the Division of Highways. For comparison of freeway impact, prediction of future pollutant levels with and without the freeway shall encompass a period beginning just prior to completion of the freeway and ending at a time twenty years subsequent to its completion.

Prediction of pollutant levels shall be accomplished using mathematical modeling techniques which incorporate meteorological data, traffic data, pollutant emission data and highway configuration to provide estimates of pollutant concentration in the study area. The models shall be verified by testing with the existing ambient air quality data gathered during the study using existing Route 101 in the study area as a line source of emissions.

To evaluate the mathematical model in terms of data requirements and validation, a sensitivity analysis of the model is required in the proposal. This analysis should examine the relative influence of the input parameters in estimating pollutant concentration.

The consultant shall deliver to the Division of Highways all raw data and a copy of all mathematical model(s) employed along with the rationale used in development. If the model(s) are computerized, a punched card source deck and user instructions shall also be supplied.

The consultant shall prepare a report for the Division which presents comprehensive summaries of pertinent data and draws conclusions as to the impact of the proposed freeway upon air quality. The report shall also discuss the relationship of the project to the State's implementation plan for achieving and maintaining the National Ambient Air Quality Standards. The report shall contain graphs showing changes in air quality with and without the freeway over the time period specified. Such graphs shall show variation in air quality at the edge of the proposed roadway and at distances of 50', 100', 200', 400', 600', 800', and 1000' from the edge on both sides of the road. Air quality in these graphs shall be shown in terms of parts per million (ppm) for each of: CO, NO_x, O_3 and hydrocarbons corrected for methane, and in micrograms per cubic-meter of particulates and lead. Contour maps showing pollutant levels under various meteorological regimes shall also be made. Any such graphs shall present a simple, clear, straightforward approach to data display and shall be suitable for use at a public presentation where local citizens may use them as a basis for discussion and decision making. Basis for the graphs shall be clearly outlined in the text. The report format shall conform to the following style:

SCOPE OF THE WORK (CONT'D)

1. Title page.
2. Abstract.
3. Table of Contents.
4. List of Figures.
5. Notation (if necessary).
6. Introduction.
7. Conclusions.

   (In a form suitable for including in the project environmental impact statement. Should be easily understood by those not familiar with technical aspects of air pollution and meteorology.)

8. Discussion.

   (Sampling and testing procedure, description of work, data analysis, etc.)

9. Bibliography.
10. Appendix.

The consultant may also be required to present his findings at one or more public hearings.

TIME SCHEDULE

Final proposal submittal date (4 copies required)	May 19, 1972.
Anticipated contract approval date	Within 60 days after submittal deadline.
Commercement of work	Within 15 days after notice of contract approval.
Submission of progress report	December 15, 1972.
Completion date	Nine (9) months after contract approval.

BUDGETARY LIMITATIONS

Contract amount not to exceed $50,000.

PROPOSAL FORMAT

The prospective consultant shall include in his proposal the following items:

1. Description of his qualifications; list of similar types of consulting contracts successfully completed, with a sample of such work; brief descriptive resumes of the principal investigators and support personnel to be employed on the project; amount of time and manpower to be expended; description of equipment and facilities to be utilized; and if subcontractors are contemplated, a description of these persons or firms and the portions and monetary percentages of the work to be done by them.

2. An overall description of the techniques by which solution of the problem will be approached.

3. Total cost of the study, a detailed breakdown of its computation showing actual rates and markups, and the preferred method of payment.